BELLCOMM, INC.

SUBJECT: Selection of a Digital Computer to Support ATM Functions - Case 620

DATE: September 4, 1968

FROM: P. S. Schaenman

ABSTRACT

The digital computer requirements for the Apollo Telescope Mount could be met by the LM Guidance Computer. However, a small, new digital computer dedicated solely to ATM requirements would provide more comfortable design margins and make the hardware and software management easier. Since the AGC approach does not appear to offer any significant cost advantage over the "new computer" approach, it is recommended that a small, new computer be purchased.

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1100 Seventeenth Street, N.W. Washington, D.C. 20036

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MEMORANDUM FOR FILE

In early July 1968, Bellcomm received a request from John Disher, MLD, to assist MLT in recommending whether or not a new computer should be purchased to support Apollo Telescope Mount functions. The principal alternatives to a new computer were: use the LM Guidance Computer; use the Abort Guidance Computer (also in the LM); or buy an additional copy of an Apollo Guidance Computer*, and mount it on the ATM-Rack.

A preliminary oral report was given by Bellcomm at H. Luskin's staff meeting on July 10. This was followed by a meeting at MSFC on July 23 with ATM project management and G&N systems management.** A final oral report was given at a meeting with John Disher on July 26.** Bellcomm's position at the latter meeting can be summarized as follows: 1) the LM Guidance Computer was functionally adequate (i.e., enough memory, speed and I/O) for the ATM job; 2) a new computer would provide more flexibility, better reliability, easier management, less software development problems, less schedule difficulties than using the LM Guidance Computer; 3) purchasing a new computer would not cost more than using the LM Guidance Computer, and possibly would cost less; 4) the Abort Guidance Computer was not adequate for the ATM job; 5) using an additional copy of the AGC would be more expensive than the other alternatives, with few advantages.

It was therefore recommended that a new computer be purchased for use on the ATM.

BACKGROUND

On April 27, 1967, MSFC asked C. Mathews, ML, to authorize an additional, new computer for the ATM. The computer was to be one of the IBM 4π-series purchased on a sole source contract. In June 1967, Mr. Mathews agreed to their request. Meanwhile, MSFC decided to go through a competitive rather than sole source procurement. A procurement specification was generated in September 1967 and revised in February 1968. A number of contractors

*The Lunar Module Guidance Computer (LGC) and Command Module Computer (CMC) are both the same type of machine, an MIT Block II Apollo Guidance Computer (AGC).

**See Appendix for list of attendees.

submitted proposals and these were discussed on June 28, 1968 with NASA Headquarters. This meeting resulted in NASA Headquarters asking MSFC to re-examine whether the LM Guidance Computer could be used in lieu of a new computer, given recent AAP schedule revisions and the potential transfer of AAP-LM management to MSFC. On July 11, 1968, MSFC responded with a TWX to H. Luskin giving their reasons why the LM Guidance Computer should not be used. Bellcomm's technical opinion was sought at that time.

EXPLANATION OF THE RECOMMENDATION

MSFC identified the following functions for an ATM digital computer:

1. orbital plane update commands,
2. experiment roll reference calculations,
3. earth occultation computations,
4. cluster occultation computations,
5. automatic gravity gradient desaturation computations,
6. momentum orientation management computations,
7. LM display driving,
8. pseudo-minimum axis of inertia computations,
9. digital telemetry buffer,
10. mission time computations and
11. sunrise-sunset prediction.

These functions were described in detail in the procurement specifications for the ATM digital computer dated February 27, 1968.

MSFC has estimated that these functions will require 3500-5000 computer words, roughly 24 bits each. Using these estimates, we can eliminate the Abort Guidance Computer from further consideration, because its 4000 word, non-expandable memory leaves too little, if any, margin at this early stage of requirements definition.

The Apollo Guidance Computer was designed to be cooled using a cold plate. Since equipment mounted on the ATM-Rack must be radiation cooled, the computer would have to be repackaged and

requalified if an additional copy of it were to be used as the ATM digital computer. This eliminated one of the main advantages for using an AGC - having a computer already qualified for and flown on manned spaceflight. When added to the disadvantages given below for using an AGC, plus the fact that the AGC is more than twice as expensive as a new machine would be, it was concluded that this alternative should also be dropped. The major tradeoff consideration was thus between a small, new computer and using the excess capacity in the LGC.

Memory

In previous studies, Bellcomm has estimated that about 27,500 words would be carried over to AAP from Apollo LGC programs.* This leaves about 9300 words in the LGC for new AAP programs, which would be adequate for the ATM requirements plus some additional programs unique to AAP. A new computer would have an 8K memory expandable to 16K, thereby providing more comfortable margins than the LGC, and the potential for later growth (for example, to implement more sophisticated weight-saving momentum dumping schemes.)

Speed

The LGC speed would be adequate since it can handle G&N functions that are more complex and time-consuming than the ATM functions, and since it would be doing no G&N during those mission phases when the ATM would be in use. Of course the new computer would be satisfactory by definition, and would provide larger speed margins due to advances that have taken place in the memory and logic circuit arts.

Input/Output

Any computer used will require a special I/O box to be built between it and the ATM and LM systems with which it will interface. The LGC has nine unused input-output channels (numbered as octal 17-27) and 76 unused but scattered input/output bits. These do not match the ATM requirements one for one, but can be made satisfactory with the appropriate multiplexing and signal conditioning in the I/O box. The new computer would have many more available I/O channels, since it does not have to be tied to the LM G&N systems. Its I/O box would therefore be considerably less complex than that for the LGC.

Reliability

The LGC was designed for the Apollo Mission and has a nominal mean time between failures (MTBF) of about 4100 hours.

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*See Table 3 in "ATM Alternative Mission Study: Impact of Computer System," Bellcomm Memorandum for File, August 9, 1968, R. T. Kleiner, B. H. Liebowitz, P. S. Schaenman.

A new computer will have a nominal MTBF of 10,000 hours. These MTBF numbers probably do not mean much however. More importantly, there will probably not be any spaceflight experience with the new computer, but it would probably have aircraft flights behind it if an off-the-shelf machine is selected. Further, the new machine will use components that are of a more advanced state of the art and presumably more reliable. The new machine would also be about half the complexity (i.e., have half the number of parts) of the LGC. In addition, as explained above, the I/O box of the new computer would be less complex and therefore more reliable. On the other hand, there will have been considerable spaceflight experience with the LGC by the time an AAP ATM mission is flown; it should be thoroughly debugged. Though we cannot prove anything about the relative reliability of the two computers, it is the judgement of the author (and that of MSFC) that the new computer will provide greater reliability.

One might ask how we cannot have confidence in the LGC but have confidence in the Command Module Computer (CMC) that must last throughout the mission, since both are the same type of machine. The answer is that the CMC need only operate on the way up and on the way down, and can lie quiescent for the majority of the mission. The ATM computer will have to operate continuously throughout the mission.

Management and Software Complexity

The interface between the ATM and the LM is much cleaner with a new computer than with the LGC for two main reasons: fewer wires across the interface, and less need to coordinate utilization of a computer among multiple users. Furthermore, the LGC software has evolved into a highly complex organism, with complex instructions and addressing, and the need to be very careful in using the 2K words of erasable memory. The new computer would have a larger instruction set, be easier to program, have all memory erasable, and only one main function - support of the ATM.

On the other hand, if the programming of the LGC were done at MIT, there would be a large pool of experienced LGC programmers to draw on; and most of its software will be similar to Apollo software. Also, using the LGC means fewer pieces of hardware to manage for AAP. Nevertheless, it is the judgement of the author that the overall hardware and software development effort for the new computer would be significantly easier than doing the job in the LGC.

Costs and Schedules

Bellcomm did not receive much first-hand information on this subject (with regard to the ATM computer), but the importance of the subject dictates its discussion. In fact, the main if not the only reason for considering the LGC for the ATM application is the potential for saving money.

Based on information gathered by MSFC, it appears that the cost of an I/O box for the LGC plus programming the new ATM functions would be about the same as the total cost of several new computers, their I/O boxes, ground checkout equipment and programming. Estimates for the LGC job were obtained from Raytheon, the manufacturer of the LGC. Estimates for the new computer came from proposals submitted by several computer manufacturers. The cost estimates for the two approaches appear to be somewhat inconsistent, probably due to differences in the requests to which the estimates were responsive. However, the apparent inconsistency is not enough to change the conclusions reached.

If the LGC computers, computer test sets and program analyses needed for the LGC approach were not already available to MSFC from the Apollo program, equipment costs and schedule feasibility would be sharply impacted. If either additional LGC's or ground test equipment, both of which are complex, and very expensive, were needed, it would nearly rule out use of the LGC on cost considerations alone. Since the test equipment is not plentiful and the current users (vendors, MIT, MSC, KSC) will probably have ongoing responsibilities under AAP, it is not obvious where equipment to be released to MSFC would come from.

SUMMARY AND CONCLUSIONS

In the evaluation of factors influencing selection of a computer for support of the ATM functions, we have reached the conclusion that procuring a small, new computer can provide significant technical and operational advantages over using the LGC. This approach also seems no more costly than using LGC's and test equipment which might already be available.

P. S. Schaenman

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Attachment
Appendix--Attendees

Appendix

Attendees at meeting on July 23, 1968 at MSFC

M. Brooks R-ASTR-NG

E. H. Cagle R-ASTR-BA

K. R. Carpenter Bellcomm

D. L. Forsythe MLA

H. Garrett R-ASTR-NDF

N. R. Gilino R-ASTR-S

J. M. Igou I-S/AA

R. Ise I-S/AA

W. J. McKinney MS-R

F. B. Moore R-ASTR-N

P. S. Schaenman Bellcomm

P. D. Schrock MLT

C. N. Swearingen R-ASTR-ND

J. B. White R-ASTR-NDF

Attendees at meeting on July 26, 1968 at NASA Headquarters

K. R. Carpenter Bellcomm

J. H. Disher MLD

D. L. Forsythe MLA

M. Savage MLT

P. S. Schaenman Bellcomm

P. D. Schrock MLT